QUANTITATIVE CORRELATION OF FOUR KEY MIDDLE AND UPPER ORDOVICIAN SECTIONS USING CONODONT RANGES

Presented in partial fulfillment of the requirements
for the degree Bachelor of Science

by

Blythe L. Hoyle

Spring, 1976

The Ohio State University

APPROVED:

Project adviser

Department of Geology and

Mineralogy

ACKNOWLEDGMENTS

The writer wishes to thank Dr. Walter C. Sweet for compiling conodont ranges from various reports for the four sections correlated and for use of manuscripts in press. She also appreciates Dr. Sweet's suggestion of the project and his stimulating discussions on the method of Shaw (1964) in and out of the classroom.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

INTRODUCTION

Shaw (1964) proposed a quantitative method to correlate stratigraphic rock sequences. His objective was to establish a Composite Standard Reference section from several individual sections. Shaw created a Composite Standard Reference section for the Cambrian Riley Formation in Texas by comparing local range-zones of species and compiling a total range-zone for each species. Qualitative stratigraphic correlations are also based on comparisons of local range-zones but Shaw was able to estimate the significance of his correlations statistically. A high degree of statistical significance permitted Shaw to divide his Composite Standard Reference section into correlatable time-units of equal length, which are smaller than time-rock-units established qualitatively for the Riley Formation.

The purpose of this study is to correlate quantitatively Middle and Upper Ordovician sequences in four areas, the Cincinnati Region, Black River valley, New York (type area of the Trenton Group), upper Lake Champlain valley and southeast Minnesota. Using ranges of conodonts it is desired to compile a Composite Standard Reference section and refine existing Middle and Upper Ordovician chronostratigraphy in these areas. In addition, it is hoped to reevaluate the conodont faunas of Sweet, Ethington and Barnes (1971) within a quantitative framework.

METHOD

To correlate stratigraphic sections according to the method of Shaw (1964) one section is chosen as a reference section which becomes the basis for an evolving Composite Standard Reference section. Points representing species' lowest and highest observed occurrences in the reference section and a second section are plotted on the abscissa and ordinate of Cartesian-coordinate axes. If fossils in the sections are time-correlative, the array describes a straight line. According to Shaw (1964) the slope of the line equals the rate of rock accumulation of one section relative to the rate of accumulation of the reference section, which is defined as 1.0. Equal units of thickness in the reference section therefore represent equal units of time in the Composite Standard section, by the equation,

$$D = R \times T,$$

where D is the measured thickness of the reference section,

R is the rate of rock accumulation of the reference section, defined as 1.0, and

T is the time that it took for the rocks to accumulate.

Solving for time,

$$T = D.$$

Since time is inherent to the fossils, time-units may be used to describe the Composite Standard section.

After plotting ranges of conodonts from two sections, points that are judged most reliable for correlation are chosen to describe the array quantitatively. Representatives of some species are not useful due to inadequate collections, lack of abundance, or long ranges. Short, non-overlapping ranges and ranges of species that have been demonstrated to be parts of an evolutionary transition were thus chosen for calculation of a pair of regressions using the method of least squares. The equations used were:

$$\hat{CS} = B_1 + A_1Y = CS + \frac{\Sigma(CS-\overline{CS})\ (Y-\overline{Y})}{\Sigma(Y-\overline{Y})^2} \times (Y-\overline{Y}),$$

$$\hat{Y} = B_2 + A_2CS = Y + \frac{\Sigma(CS-\overline{CS})\ (Y-\overline{Y})}{\Sigma(CS-\overline{CS})^2} \times (CS-\overline{CS}),$$

where B is the regression coefficient (the slope of the line which is the rate of rock accumulation of one section relative to the other),

A is the intercept coefficient (the position of the base of one section relative to the base of the other section),

$\hat{CS}$ (read Composite-Standard computed) is the CS value of the Y variable projected into the Composite Standard, and,

$\hat{Y}$ (read Y computed) is the Y value of the Composite-Standard variable projected into the other section.

The coefficient of correlation, r, is calculated ($r = \sqrt{B_1 \times B_2}$) to indicate the extent to which the points describe a linear relationship. If the equations represent exactly the same line, the regression coefficients are inverse and r = 1.0. If the regression equations do not describe the same line, r is less than 1.0. High r values indicate that enough data were used such that the correlations are statistically significant at a given confidence interval.

The measure of dispersion in the data used to compute the regression equations is expressed by the standard error of estimate, S, by the equations,

$$S_{\hat{CS}} = \sqrt{\frac{\Sigma(CS-\overline{CS})^2}{n}}, \quad \text{and} \quad S_{\hat{Y}} = \sqrt{\frac{\Sigma(Y-\overline{Y})^2}{n}}.$$

The same points used to calculate the regression equations are used to compute S. To establish fiducial limits the S values are multiplied by a statistic called t which adjusts for arrays of fewer than 30 points. The t value is chosen on the basis of the number of points used to calculate S, and the desired confidence interval. The resultant limits represent the "resolving power" of the regression equations. The Composite Standard

Reference section may not be divided into units that are so thin they cannot be recognized in every section which was used to compile the Composite Standard section.

To establish a Composite Standard Reference section from comparison of two sections, the position of the ranges in the section to be correlated are projected into the reference section using the appropriate CS equation. The lowest base and highest top for each species is chosen and the resultant compilation becomes an intermediate Composite Standard Reference section. The next section to be correlated is compared with values in the intermediate Composite Standard and new ranges are established based on the additional data.

After all the sections have been correlated and a Composite Standard Reference section compiled from all available data, the sections are recorrelated in the original order of comparison. Recorrelation assures that data from all sections are equally emphasized in synthesis of a single Composite Standard Reference section. Recorrelation is continued until the ranges of species are the same at the end of successive rounds of recorrelation.

STRATIGRAPHIC SECTIONS

Each of the four stratigraphic sections correlated in this study represents a composite of several individual Middle and Upper Ordovician sections sampled for conodonts in the following areas: 1) Cincinnati Region-Kentucky, Ohio, Indiana (Votaw, 1972; Sweet, 1976, in press), 2) Black River valley, New York (Schopf, 1966; Votaw, 1972), 3) upper Lake Champlain valley-New York, Vermont (Roscoe, 1973), 4) southeast Minnesota (Webers, 1966). Conodont ranges for each region were compiled from the above studies by Walter C. Sweet (personal communication).

Consistent taxonomy and nomenclature were desirable in establishing the regional sections. However, according to Shaw (1964, p. 193-195), taxonomic misidentifications are either self-eliminating or tend to lower the standard error of estimate rather than affect the actual correlations. Conodonts collected by Roscoe (1973) and Votaw (1972) as well as a reference collection of specimens by Schopf (1966) are stored in the Micropaleontological Collections, Department of Geology and Mineralogy, The Ohio State University. However, Sweet did not study specimens collected by Webers (1966) which are in the University of Minnesota Paleontological Collections.

Sweet used nomenclature associated with multi-element taxonomy to compile the regional sections. Votaw (1972), Roscoe (1973) and Sweet (1976, in press) had previously classified their collections of conodonts into multi-element groups. Along with Sweet and Bergström (1962), Bergström and Sweet (1966), Webers (1966) and Schopf (1966) were some of the first workers to propose that conodont-elements be grouped into natural assemblages. However, Sweet modified some of the nomenclature employed by Webers (1966) and Schopf (1966) when he compiled the ranges from their reports.

In this paper the stages and series for the upper Middle and Upper Ordovician proposed by Sweet and Bergström (1971) are employed. They favored division of the upper part of the Champlainian Series into the Rocklandian, Kirkfieldian and Shermanian Stages, having correlated Kay's (1968) Cobourgian Stage with the Edenian and lower Maysvillian Stages of the Cincinnatian Series. Sweet and Bergström (1976, in press) used Whiterockian, Chazyan and Black Riveran as Stages for the lower Champlainian Series and these divisions are used in this paper.

Cincinnati Region

Conodont ranges in the Cincinnati Region were compiled from over 60 individual sections. The resultant stratigraphic column represents a 1595-foot sequence of rocks, which accumulated from mid-Black Riveran through

Richmondian time.

Sweet computed ranges for the lower 545 feet of the Cincinnati-Region composite from Votaw's (1972) study of conodonts from the Cominco American core (CA-38) drilled near Minerva, Mason County, Kentucky. This interval extends through the pre-Edenian Camp Nelson, Oregon and Tyrone Formations to the base of the Lexington Limestone.

Sweet (1976, inpress) compiled ranges for the remaining 1050 feet of the Cincinnati-Region section by comparing conodont relative-abundance logs representing four general areas in Kentucky, Ohio and Indiana. Bergström and Sweet (1966) and Sweet and Bergström (1971) proposed that vertical fluctuations in relative abundances of conodont species were caused by environmental factors and are time-correlative throughout the Cincinnati Region basin. Sweet (1976, in press) graphed and correlated logs based on relative percentages of Phragmodus undatus, Plectodina furcata, Aphelognathus politus, Oulodus spp. and Rhipidognathus symmetricus. He found that thicknesses of rocks representing major conodont-abundance cycles do not vary laterally to any great extent.

The log for the southeast Cincinnati Region was initially plotted from sections sampled near Clays Ferry, Kentucky. Data from other sections in the southeast area were compared and correlated with the Clays Ferry sections and a final composite log was established for this area. A relative-abundance log for the Maysville, Kentucky, area was compiled primarily from the Cominco American core (CA-38), and sections near Maysville and Isaacs Creek, Adams County, Ohio. The city of Cincinnati area of southwest Ohio and Indiana was correlated from frequency logs of conodonts collected from a 626-foot core drilled by the Texas Eastern Transmission Corporation near Middletown, Ohio, and sections near Cincinnati, Ohio, and China, Jefferson County, Indiana. The fourth log was compiled from a 1010-foot core drilled by the

Indiana Geological Survey near New Point, Decatur County, Indiana. Boundaries for the Edenian, Maysvillian and Richmondian Stages were placed 860 feet, 1090 feet and 1300 feet, respectively, above the base of the final composite log. Forty-five species are represented in this composite section.

Black River Valley

Sweet (personal communication) compared relative-abundance logs for the type area of the Trenton Group in New York by a method similar to that used for the Cincinnati Region. He plotted logs of relative percentages of *Phragmodus undatus*, and species of *Belodina* and *Panderodus*, against the remaining species for eight sections of Schopf (1966). After aligning the sections vertically with respect to major abundance fluctuations, Sweet adjusted the sections so that the position of the *Amorphognathus tvaerensis*-*A. superbus* evolutionary transition was at about the same horizontal level in all sections in which it occurred. He then made one composite log for Schopf's sections and added to the bottom of this section data from Votaw's (1972) collection from Roaring Brook, Martinsburg, New York. Schopf (1966) had sampled beds higher in the same Roaring Brook section and those data were included in Sweet's log. The resultant composite section is about 630 feet thick and includes the ranges of 23 conodont species.

Upper Lake Champlain Valley

Correlation of sections in the upper Lake Champlain valley was complicated by abrupt lateral lithofacies changes, lack of long continuous outcrops and the occurrence of the Champlain Thrust Fault, which follows the eastern shore of Lake Champlain (Roscoe, 1973). Sweet (personal communication) correlated a section at Crown Point, New York representing the western lithofacies, with a section representing the eastern facies in the Highgate Springs Thrust Slice, Highgate, Vermont, using the method of Shaw (1964). He used the thicker Highgate Springs section as a reference section into which he projected values computed from the Crown Point section according to the equation,

$$\widehat{HGS} = .786\ CP + 191.9.$$

The coefficient of correlation was significant at the 99 percent confidence interval. Ranges of 21 conodont species are contained in the resultant 350-foot composite section. Rocks in this area were deposited during Chazyan and Black Riveran time.

Southeast Minnesota

Webers (1966) identified over 35,000 conodont-elements from seven locations in southeast Minnesota representing five Middle and Upper Ordovician formations. One section was sampled for each formation except the basal Glenwood Shale. Due to scarcity of specimens in the Glenwood, material was collected from three sections. The other formations in ascending order are the Platteville, Decorah, Galena and Dubuque Formations. Webers collected samples from every bed in all formations except the Decorah Shale in which each sample represents one stratigraphic foot. Conodont ranges were compiled by Sweet (personal communication) from Webers' (1966) chart showing stratigraphic position and abundance of specimens. The Minnesota section is approximately 265 feet thick and includes representatives of 23 conodont species.

DISCUSSION OF CALCULATIONS

The Cincinnati-Region section was chosen as a base section because it contains representatives of more conodont species (27) common to at least one other section and has a greater thickness (1595 feet) than any other section. The thickness of the reference section allowed finer resolution of ranges than would have been possible if ranges had been projected into a section of lesser thickness. The other sections were correlated with the reference section in the following order: Black River valley, upper Lake

Champlain valley, southeast Minnesota. This order reflected the decreasing number of representatives of conodont species each section contained in common with the other sections, the geographic distribution of conodont species, and, to a certain extent, the thickness of each section. Original ranges of conodonts from each section are listed in Appendix A. In Table 1 the final regression equations and their coefficients of correlation (r), standard errors of estimate (S), and fiducial limits are listed for the Black River valley, upper Lake Champlain valley and Minnesota sections. Fiducial limits do not exist for the Cincinnati-Region section. Ranges in the reference section are not subject to modification or evaluation statistically. Graphs, calculations and intermediate Composite Standard sections are in Appendix B.

The sections were recorrelated three times with coefficients of correlation that are significant at the 99 percent confidence interval. Such high r values indicate that the data used in the correlations are adequate to indicate linear relationships and that there is less than one chance in a hundred that these could have arisen by chance. The 99 percent confidence interval may be more rigorous than is justified by the methods used in compilation of the ranges, by errors in collection, or by variances in identification. However, the fact that the correlations are significant at such a high level probably indicates that few outside errors were introduced. As recorrelation progressed r values tended to increase because correlations were based on integration of all the data, and fewer points were used to define arrays and calculate the equations. Regression equations for the third round of recorrelation were not calculated since ranges of species that would have been used to compute them were the same values as those used in the calculations of the second round of recorrelations. In successive recorrelations bases of ranges tended to move above the line of correlation and tops migrated below the line in an effect Shaw (1964) called channeling. This signifies

STATISTICS AFTER FINAL RECORRELATION

Section	Regression Equation	n	r	S	$t_{.05}$	95 % Limits
Black River valley	$\widehat{CS} = 1.2210\ BRV + 345.1283$	5	.9999651	1.7882	3.182	5.6901
	$\widehat{BRV} = 0.8190\ CS - 282.6272$			1.4651		4.6619
Lake Champlain valley	$\widehat{CS} = 5.9903\ LCV - 1193.1648$	4	.9989849	8.8436	4.303	38.0540
	$\widehat{LVC} = 0.1666\ CS + 199.3126$			1.4735		6.3405
Minnesota	$\widehat{CS} = 3.0648\ M + 416.2111$	3	.9999826	1.5351	12.706	19.5050
	$\hat{M} = 0.3263\ CS - 135.7936$			0.5496		6.9832

TABLE 1. Final regression equations, number of points used to calculate them (n), coefficients of correlation (r), standard errors of estimate (S), t values for the 95 percent confidence interval ($t_{.05}$) and fiducial limits at the 95 percent confidence interval. These values were established after three rounds of recorrelation.

that incomplete ranges were being plotted from the original sections and that ranges in the Composite Standard were being established which were relatively complete within the confines of the given data.

The final regression equations indicate rates of rock accumulation in each section relative to the Composite Standard Reference section in which the rate of accumulation is by definition 1.0. Any point can now be projected into the Composite Standard Reference section from the individual sections or into each section from the Composite. For example, previous difficulty in correlation of the rocks of the New York area with the Minnesota strata can be solved by projecting New York points into the Composite Standard section using the $\widehat{CS}$ equation and projecting the $\widehat{CS}$ values from the Composite into the Minnesota section using the $\hat{M}$ equation.

The rate of accumulation of the rocks in the Black River valley was nearly the same as the rate of accumulation of the Cincinnati-Region strata. Thicknesses of time-correlative rocks in these two areas should not vary to great extent. The rate of accumulation of rocks in the upper Lake Champlain valley was nearly six times that of the Composite section. This area is not on the North American craton as are the other areas. The base of the upper Lake Champlain section projected into the Composite Standard Reference section is over 1000 feet below the base of the Cincinnati-Region section. These older rocks are technically part of the Composite section but will not be considered here since they are not time-correlative with any of the other sections. The rate of accumulation in the Minnesota area was about three times that of the Composite Standard, possibly due to emergence of the Transcontinental Arch in the late Cambrian and early Ordovician and deposition of sediments off the arch.

Fiducial limits for each section were established at the 95 percent confidence interval. The upper Lake Champlain valley section generated the

STRATIGRAPHIC CONTROL OF RANGES IN THE COMPOSITE STANDARD REFERENCE SECTION

Cincinnati Region

T	Amorphognathus ordovicicus (3)
T	Bryantodina abrupta (3)
T	B. staufferi (2)
B	B. typicalis (2)
B	Curtognathus typus (3)
T	Drepanoistodus suberectus (4)
B	Erismodus radicans (2)
T	Icriodella superba (4)
B,T	Panderodus gracilis (4)
B	P. panderi (2)
B	Paroistodus ? mutatus (4)
B	Phragmodus inflexus (3)
T	P. undatus (4)
B	Plectodina aculeata (3)
B,T	P. furcata (3)
B	P. nsp. (2)
B,T	Protopanderodus sp. of P. insculptus (3)
B,T	Rhodesognathus elegans (3)
B	Staufferella falcata (4)

23 ranges, 13 bases, 10 tops

Black River Valley

B,T	Amorphognathus superbus (2)
B,T	A. tvaerensis (2)
B,T	Belodina monitoreusis (2)
B	Bryantodina abrupta (3)
B	Coelocerodontis trigonius (2)
T	Erismodus radicans (2)
B	Icriodella superba (4)
T	Phragmodus cognitus (2)
B	P. undatus (4)
T	Plectodina aculeata (3)

13 ranges, 7 bases, 6 tops

Upper Lake Champlain Valley

B,T	Belodella niger (2)
B	Belodina compressa (4)
B	Bryantodina staufferi (2)
T	Curtognathus typus (3)
B	Drepanoistodus suberectus (4)
B	Periodon grandis (4)
T	Phragmodus inflexus (3)
T	Plectodina nsp (2)
T	Polyplacognathus ramosus (4)
B,T	"Scandodus" superbus (3)

12 ranges, 6 bases, 6 tops

Minnesota

B	Amorphognathus ordovicicus (3)
T	Belodina compressa (4)
T	Bryantodina typicalis (2)
T	Coelocerodontis trigonius (2)
T	Panderodus panderi (2)
T	Paroistodus ? mutatus (4)
T	Periodon grandis (4)
B	Phragmodus cognitus (2)
B	Polyplacognathus ramosus (4)
T	Staufferella falcata (4)

10 ranges, 3 bases, 7 tops

TABLE 2. Sections and the bases and tops of ranges they control in the Composite Standard Reference section. Numbers in parentheses are the number of sections in which representatives of a species occur.

highest limits. As a result the controlled portion of the Composite Standard Reference section (1225 feet) was divided into 32.5 equal time units that are 40 feet thick. These correlatable units represent a considerably more refined division of the Middle and Upper Ordovician sequences considered than now exists.

Fifty-eight bases and tops were established for the 29 conodont species that are represented in at least two sections. Twenty-seven additional species are represented in only one section and were not useful for correlation. Of the 58 possible bases and tops, the Cincinnati-Region section controlled 23 (39.7 percent), Black River valley, 13 (22.4 percent), upper Lake Champlain valley, 12 (20.7 percent), and Minnesota, 10 (17.2 percent). Sections are listed with the species whose ranges they control in Table 2.

CORRELATION OF SECTIONS

After the final regression equations were calculated, the regional sections were correlated with the Cincinnati Region by projecting formational boundaries, where known, into the units of the Composite Standard Reference section for comparison. It was difficult to correlate formations of the Black River valley and upper Lake Champlain valley with those of the Cincinnati Region directly. Since each of the sections was a compilation of several other sections, formation boundaries could not be precisely located in the composite of each section. Webers' study (1966), however, very clearly denoted the exact stratigraphic locations of various formations. These formations were easily converted to Composite-Standard-Reference-section units and compared with the Cincinnati Region. In general, temporal relationships for the Cincinnatian Series were compared rather than correlation of formations. The correlations that were proposed are in reasonable agreement with correlations for the Middle and Upper Ordovician by Sweet and Bergström (1976, in press). Their chart is in Figure 1.

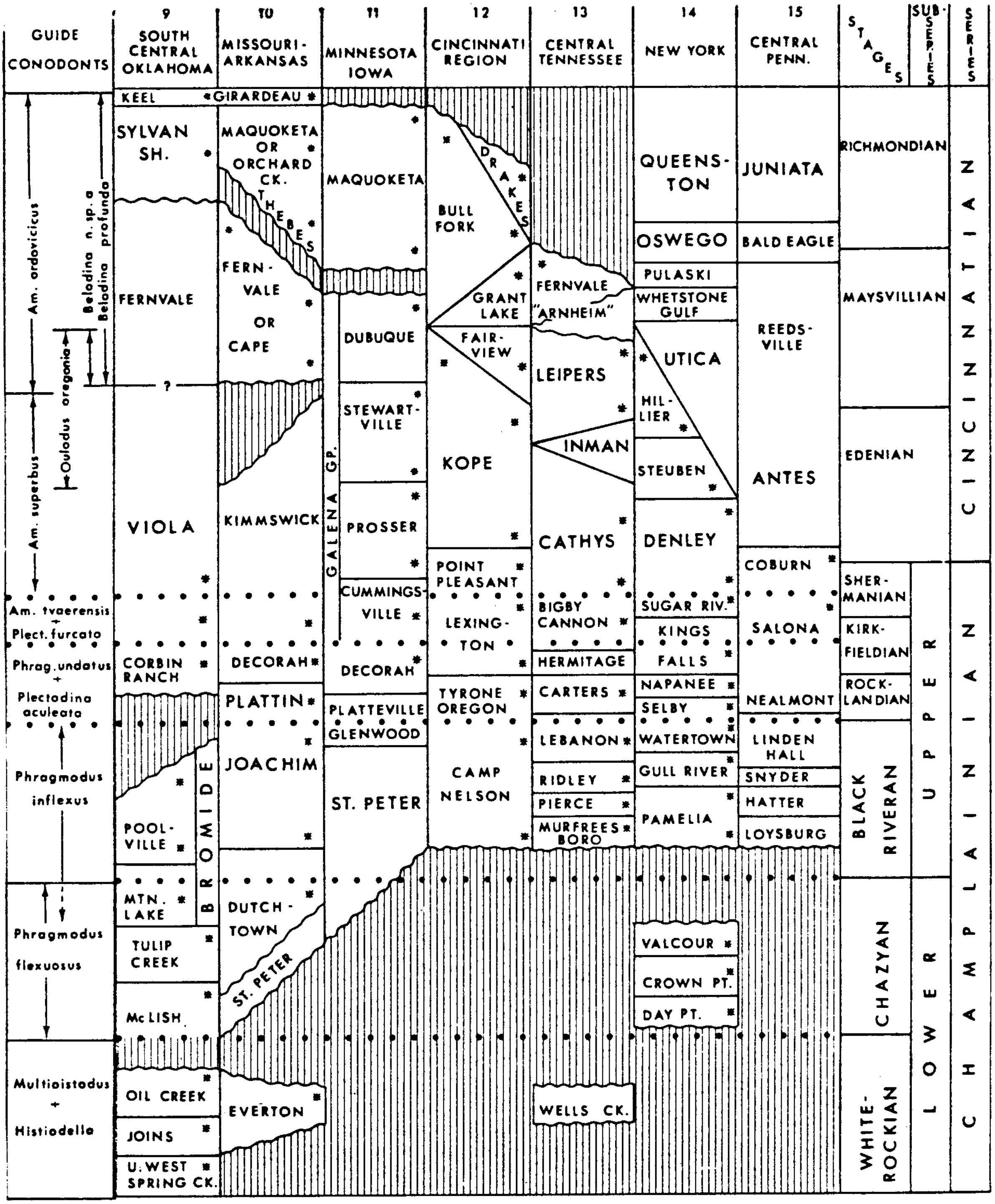
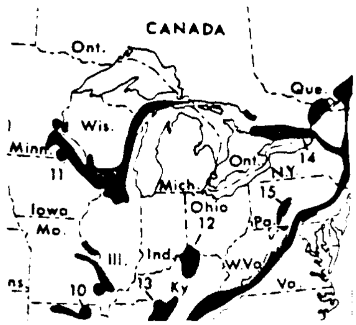


FIGURE 1. Correlation of Middle and Upper Ordovician formations using guide conodonts in eastern North America, taken from Sweet and Bersgström (1976, in press).



Black River Valley

Correlation was complicated by confusion between nomenclature of rock- and time-rock units. Schopf (1966), following Kay (1937), used the terms Rockland, Kirkfield and Sherman as lithologic units in his study of the Trenton Group. The boundaries of Schopf's formations essentially coincided with boundaries of Kay's (1968) stages. The base of the Pamelia Formation is 345 feet above the base of the Cincinnati Region composite section, approximately corresponding to the Camp Nelson Limestone. The boundary between the Rocklandian and Kirkfieldian Stages projected into the Composite Standard Reference section nearly coincides with the base of the Lexington Limestone. The upper Denley Limestone is Edenian in age and the top of the Black Rvier valley section is early Maysvillian in age.

Upper Lake Champlain Valley

Positions of the Valcour Formation-Black River Group and Black River Group-Glen Falls Formation boundaries were projected into the Highgate Springs, Vermont, section by the equation previously calculated by Sweet. The thickness of strata represented by both the Highgate Springs and Crown Point sections extended from 191.9 feet to about 740 feet above the base of the Highgate Springs reference section. This thickness was then projected into the Composite Standard Reference section. The base of the Valcour Formation is thus 40 feet below the base of the Cincinnati-Region section. The top of the Valcour is the boundary between the Chazyan and Black Riveran Stages. The Black River Group-Glen Falls boundary is at the base of the Lexington Limestone.

Minnesota

The basal Glenwood Shale and the Platteville Formation correspond to the Oregon and Tyrone Limestones of the Cincinnati Region. The upper two thirds of the Decorah Shale, the Cummingsville Member of the Galena Formation and the lower half of the Prosser Member of the Galena Formation correlate with the Lexington Limestone. The remaining Prosser strata and most of the rocks of the Stewartville Member of the Galena Formation were deposited during Edenian time and the Dubuque Formation was laid down in Maysvillian time and corresponds to parts of the Fairview and Grant Lake Formations of the Cincinnati Region.

CONODONT FAUNAS

The conodont faunas of Sweet, Ethington and Barnes (1971) revised by Sweet and Bergström (1976, in press) were reevaluated with respect to ranges quantitatively established in this study. Fairly good agreement was noted between the revised Faunas 6 through 12 of Sweet and Bergström (1976, in press) and the arrangement of ranges established in the Composite Standard Reference section. The ranges from the Composite Standard Reference section of the same species plotted by Sweet and Bergström (1976, in press) are in Figure 2. All but three of the species they plotted are represented in at least one of the sections correlated in this study. The Composite Standard Reference section indicates relative lengths of time during which the rocks in which each Fauna occurred were deposited. It is not possible to make such comparisons from Sweet and Bergström's (1976, in press) diagram or the original chart from Sweet, Ethington and Barnes (1971).

According to Sweet, Ethington and Barnes (1971) the division between Faunas 6 and 7, based on the last occurrence of *Phragmodus flexuosus* and the first appearance of *P. inflexus*, coincides approximately with the boundary between the Chazyan and Black Riveran Stages of the Champlainian Series. No overlap between these ranges was noted. However, the ranges of these species in the Composite Standard Reference section overlap by a significant amount;

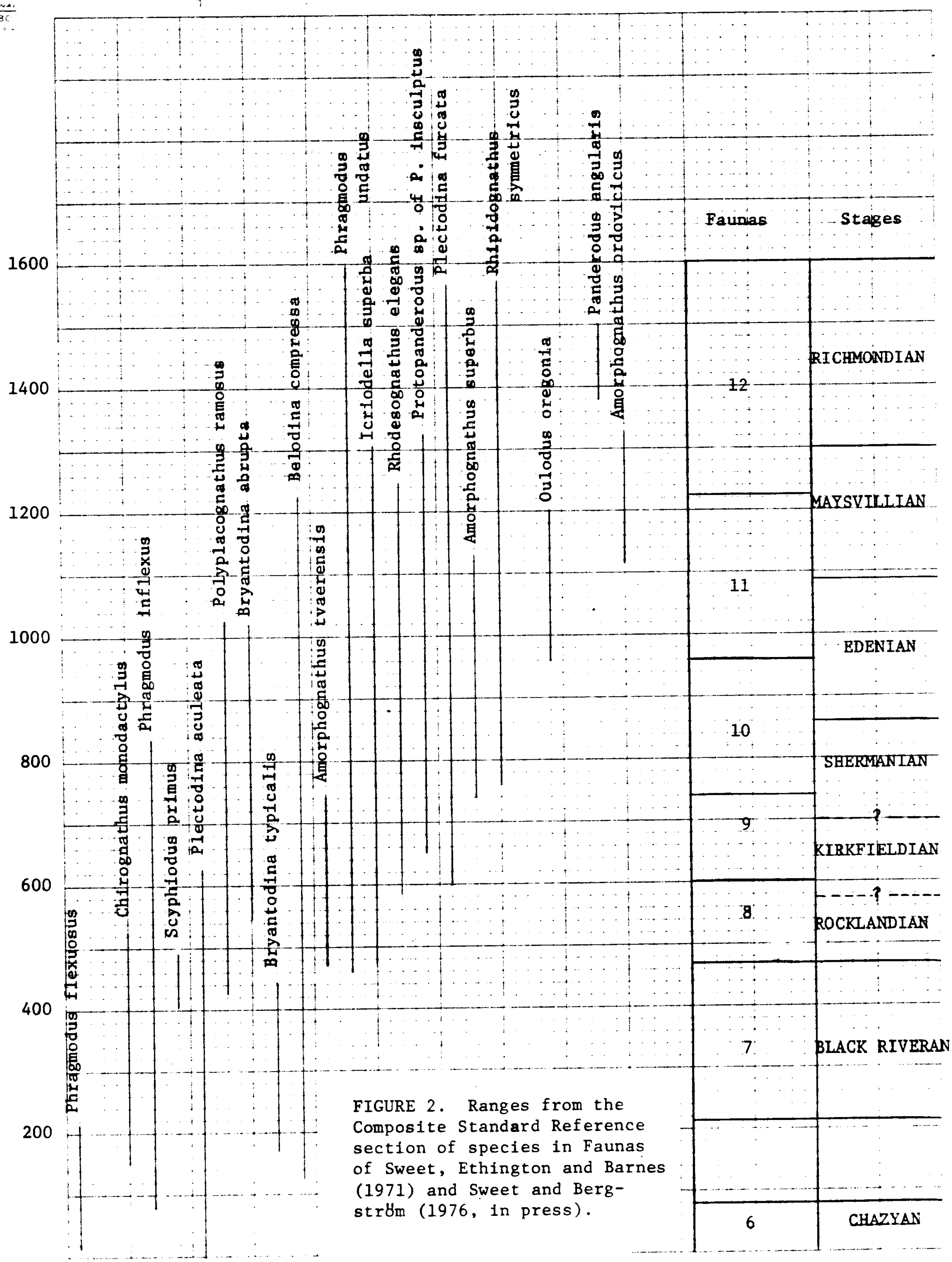


FIGURE 2. Ranges from the Composite Standard Reference section of species in Faunas of Sweet, Ethington and Barnes (1971) and Sweet and Bergström (1976, in press).

that is, the amount of overlap was greater than the fiducial limits of the upper Lake Champlain valley section, which controlled the value of the range-top of P. flexuosus. The base of P. inflexus was controlled by data from the Cincinnati-Region section, but this species is also represented in the upper Lake Champlain valley and Minnesota sections. Specimens of P. flexuosus were only collected from the upper Lake Champlain valley section. The statistically significant overlap indicates that one or both Faunas should be reexamined and perhaps redefined.

Sweet, Ethington and Barnes (1971) designated the boundary between Faunas 7 and 8 as the last occurrence of Phragmodus inflexus and the first appearance of P. undatus. Representatives of "European" species Amorphognathus tvaerensis, Icriodella superba and Rhodesognathus elegans also occur at the beginning of Fauna 8 (for further discussion of conodont provincialism see Bergström, 1971; Sweet, Ethington and Barnes, 1971; Sweet, et. al., 1959). In the Composite Standard Reference section the bases of the ranges of the latter four species are at about the same level, but the top of the range of Phragmodus inflexus, used by Sweet, Ethington and Barnes (1971) to mark the top of the range of Fauna 7 is higher in the Composite Standard than the bases of the ranges of the other species.

The top of the range of Fauna 8 of Sweet, Ethington and Barnes (1971) was placed at the highest occurrence of Plectodina aculeata and the lowest occurrence of P. furcata. In the Composite Standard Reference section these ranges overlap by an insignificant amount. The upper limit of Fauna 9 of Sweet and Bergström (1976, in press) was set at the Amorphognathus tvaerensis-A. superbus evolutionary transition. These ranges also succeed each other with no overlap in the Composite Standard Reference section. This transition occurs slightly below the boundary of the Edenian Stage of the Cincinnatian Series in Sweet and Bergström's (1976, in press) designation of the Faunas and in the Composite Standard Reference section.

Fauna 11 was determined by Sweet, Ethington and Barnes (1971) as the range of Oulodus oregonia in the eastern United States and by the range of Belodina sp. A in the western United States. Representatives of O. oregonia occurred only in the Cincinnati-Region section, but the top of its range coincides with the top of the range of B. compressa, which according to Sweet, Ethington and Barnes (1971) also occurs at the top of the range of Fauna 11. B. sp. A has not been reported from any of the areas considered.

Fauna 12, extending through the upper Maysvillian and all of the Richmondian Stages, is characterized by Amorphognathus ordovicicus, Panderodus angularis and P. staufferi (not shown in Figure 2) by Sweet, Ethington and Barnes (1971). These species also occur together in the Composite Standard Reference section.

LIST OF CONCLUSIONS

1. Using the method of Shaw (1964) ranges of conodonts from Middle and Upper Ordovician sequences in New York, the Cincinnati Region and Minnesota were compiled into a Composite Standard Reference section at a sufficiently high degree of statistical confidence to assure that enough data were used to make the correlations significant.
2. The Composite Standard Reference section is divisible into 32.5 units of equal length, which can be recognized at the 95 percent confidence level in all sections compiled. These divisions represent a more refined chronostratigraphy for the North American Middle and Upper Ordovician than does the more familiar sequence of series and stages, which was produced by qualitative correlations.
3. Correlation of formations was accomplished with various degrees of success. Due to the method of compilation of three of the sections, formational boundaries were not known and could only be estimated. Reasonable agreement exists

between the correlation of formations proposed here and the correlations put forth by Sweet and Bergström (1976, in press).

4. The ranges of conodonts in the Composite Standard Reference section define essentially the same Faunas as were established by Sweet, Ethington and Barnes (1971), except that ranges of the species used to indicate the division between the Chazyan and Black Riveran Stages overlap. This overlap is statistically significant at the 95 percent confidence interval. In all cases in which the Faunas of Sweet, Ethington and Barnes (1971) diverged from the ranges in the Composite Standard Reference section, the disparity is due to lengthening of ranges by integration of data from several sections mathematically.

REFERENCES CITED

Bergström, S. M., 1971, Conodont biostratigraphy of the Middle and Upper Ordovician of Europe and eastern North America: Symposium on Conodont Biostratigraphy (W. C. Sweet and S. M. Bergström, ed.), Geol. Soc. America Mem. 127, p. 83-162.

Bergström, S. M., and Sweet, W. C., 1966, Conodonts from the Lexington Limestone (Middle Ordovician) of Kentucky and its lateral equivalents in Ohio and Indiana: Am. Paleontology Bull., v.50, no. 229, p. 269-441.

Kay, G. M., 1937, Stratigraphy of the Trenton Group: Geol. Soc. America Bull. 48, p. 233-302.

__________, 1968, Ordovician formations in northwestern New York: Natur. Can., v. 95, p. 1373-1378.

Roscoe, M. S., 1973, Conodont biostratigraphy and facies relationships of the lower Middle Ordovician strata in the upper Lake Champlain valley: unpubl. M. Sc. Thesis, The Ohio State University, 125 p.

Schopf, T. J. M., 1966, Conodonts of the Trenton Group (Ordovician) in New York, southern Ontario, and Quebec: New York State Mus. and Sci. Serv. Bull. 405, 105 p.

Shaw, A. B., 1964, Time in stratigraphy: McGraw-Hill Book Company, New York, 365 p.

Sweet, W. C., 1976, Conodonts and conodont biostratigraphy of post-Tyrone Ordovician rocks of the Cincinnati Region: in U. S. Geol. Survey Prof. Paper, in press.

Sweet, W. C., and Bergström, S. M., 1962, Conodonts from the Pratt Ferry Formation (Middle Ordovician) of Alabama: Jour. Paleontology, v. 36, p. 1214-1252.

__________, and __________, 1971, The American Upper Ordovician Standard. XIII. A revised time-stratigraphic classification of North American upper Middle and Upper Ordovician rocks: Geol. Soc. America Bull. 82, p. 613-628.

__________, and __________, 1976, Conodont biostratigraphy of the United States midcontinent: Symposium on the Ordovician System, M. G. Bassett, ed., University of Wales Press, in press.

__________, Ethington, R. L., and Barnes, C. R., 1971, North American Middle and Upper Ordovician conodont faunas: Symposium on Conodont Biostratigraphy (W. C. Sweet and S. M. Bergström, ed.), Geol. Soc. America Mem. 127, p. 163-193.

_____________, Turco, C. A., Warner, E., and Wilkie, L. C., 1959, The American Upper Ordovician Standard. I. Eden conodonts from the Cincinnati Region of Ohio and Kentucky: Jour. Paleontology, v. 33, p. 1029-1068.

Votaw, R. B., 1972, Conodont biostratigraphy of the Black River Group (Middle Ordovician) and equivalent rocks of the eastern midcontinent, North America: unpubl. Ph. D. Dissertation, The Ohio State University, 170 p.

Webers, G. F., 1966, The Middle and Upper Ordovician conodont faunas of Minnesota: Minnesota Geol. Survey Spec. Publ. SP-4, 123 p.

APPENDIX A

RANGE CHART

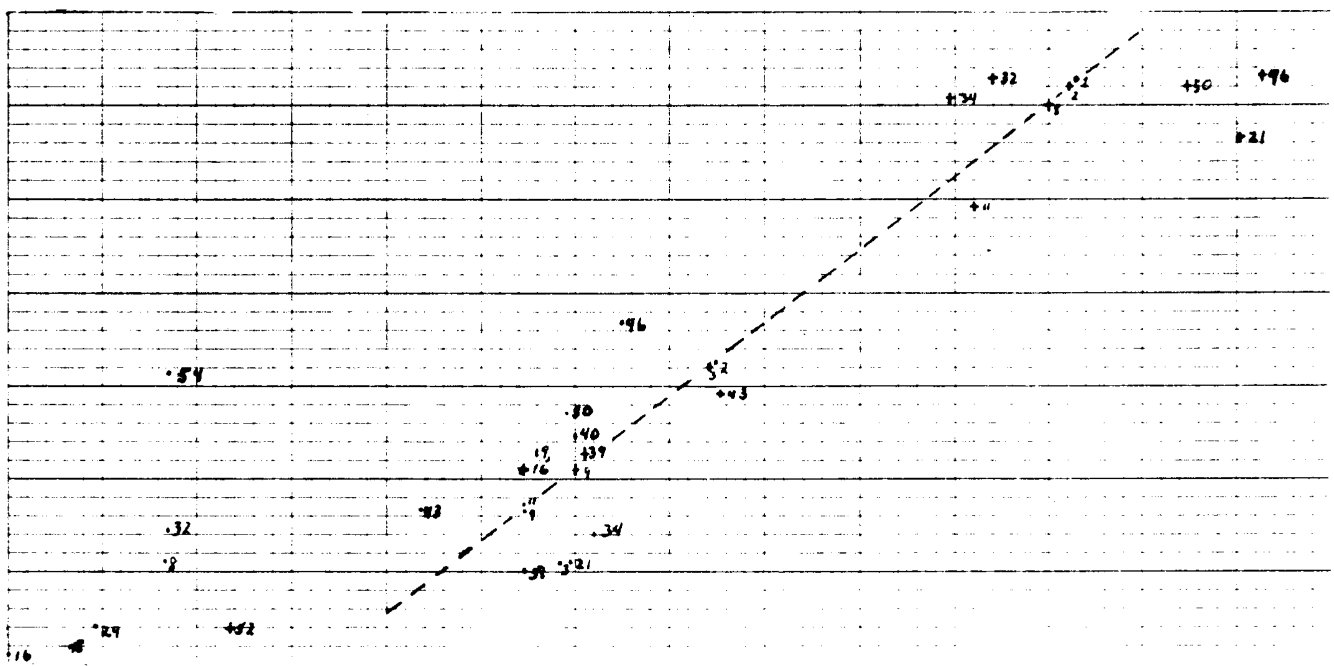
		Cincinnati Region	Black River valley	upper Lake Champlain valley	Minnesota
1	*Amorphognathus ordovicicus*	1130-1330	630	-	228-264
2	*A. superbus*	750-1125	325-625	-	-
3	*A. tvaerensis*	585-745	110-325	-	-
4	*Aphelognathus kimmswickensis*	545-629	-	-	-
5	*A. politus*	670-1570	-	-	-
6	*Appalachignathus delicatulus*	95-221	-	-	-
7	*Belodella niger*	172-210	-	227-235	-
8	*Belodina compressa*	172-1110	102-600	227-348	4-264
9	*B. monitoreusis*	545-600	? 165-210	-	-
10	*B. profunda*	1345-1560	-	-	-
11	*Bryantodina abrupta*	550-1020	167-495	292-331	-
12	*B. staufferi*	615-955	-	300-326	-
13	*B. typicalis*	166-188	-	-	1-8.5
14	*Chirognathus monodactylus*	150-524	-	-	-
15	*Coelocerodontis trigonius*	-	320-600	-	169-257
16	*Curtognathus typus*	0-545	10-210	257-326	-
17	*Cyrtoniodus sinclairi*	1365-1585	-	-	-
18	*Drepanoistodus suberectus*	65-1585	20-510	0-352	0-264
19	*Erismodus radicans*	0-545	10-210	-	-
20	Fibrous conodonts	0-1100	-	-	-
21	*Icriodella superba*	590-1305	110-570	294-313	239-260
22	*Oulodus mediocris*	-	-	-	11-68
23	*O. oregonia*	955-1200	-	-	-
24	*O. robustus*	1095-1545	-	-	-
25	*O. subundulatus*	685-950	-	-	-

		Cincinnati Region	Black River valley	upper Lake Champlain valley	Minnesota
26	Q. ulrichi	1350-1570	-	-	-
27	Panderodus angularis	1380-1500	-	-	-
28	P. feulneri	-	-	-	60-264
29	P. gracilis	95-1545	40-620	223-239	0-264
30	P. panderi	575-1105	-	-	62-264
31	P. staufferi	1370-1535	-	-	-
32	Paroistodus ? mutatus	172-1040	143-630	313	134-261
33	Periodon aculeatus	-	-	13-167	-
34	P. grandis	610-995	143-605	283-344	74-264
35	Phragmodus cognitus	-	165-205 ?	-	13-36
36	P. flexuosus	-	-	212-235	-
37	P. inflexus	80-441	-	294-313	1-8.5
38	P. undatus	545-1595	100-623	292-352	26-237
39	Plectodina aculeata	0-610	40-230	-	0-68
40	P. furcata	600-1565	242-630	-	82-264
41	P. nsp.	172-502	-	235-278	-
42	P. ? undulata	1175-1560	-	-	-
43	Polyplacognathus ramosus	436-755	165-298	331-336	7-68
44	P. sweeti	-	-	268	-
45	Pravognathus idoneus	-	-	-	17-46
46	Protopanderodus sp. of P. insculptus	650-1325	369-630	-	176-233
47	Pygodus serrus	-	-	110-145	-
48	Rhipidognathus rowlandeusis	1145-1350	-	-	-
49	R. symmetricus	760-1570	-	-	-
50	Rhodesognathus elegans	585-1245	270-620	300-349	-
51	Scandodus sp. of S. dissimilaris	680-745	-	-	-

		Cincinnati Region	Black River valley	upper Lake Champlain valley	Minnesota
52	"Scandodus" superbus	80-235	20-40	? 30-303	-
53	Scyphiodus primus	-	-	-	0-25
54	Staufferella falcata	172-1130	317-599	254	0-260
55	Synprioniodina ? forsenta	685-940	-	-	-
56	"Tetraprioniodus" breviconus	-	-	-	11-20

APPENDIX B

Cincinnati, Black River Valley



	X	Y	$(X-\bar{X})$	$(Y-\bar{Y})$
B9	545	165	-251.1111	-199.1111
B11	550	167	-246.1111	-197.1111
T9	600	210	-196.1111	-154.1111
T39	610	230	-186.1111	-134.1111
T3	745	325	-51.1111	-39.1111
B2	750	325	-46.1111	-39.1111
T8	1110	600	313.8889	235.8889
T2	1125	625	328.8889	260.8889
B1	1130	630	333.8889	265.8889

$\underline{n} = 9$

$\bar{X} = 796.1111$

$\bar{Y} = 364.1111$

$\Sigma(X-\bar{X})^2 = 519638.8889$

$\Sigma(Y-\bar{Y})^2 = 317696.8889$

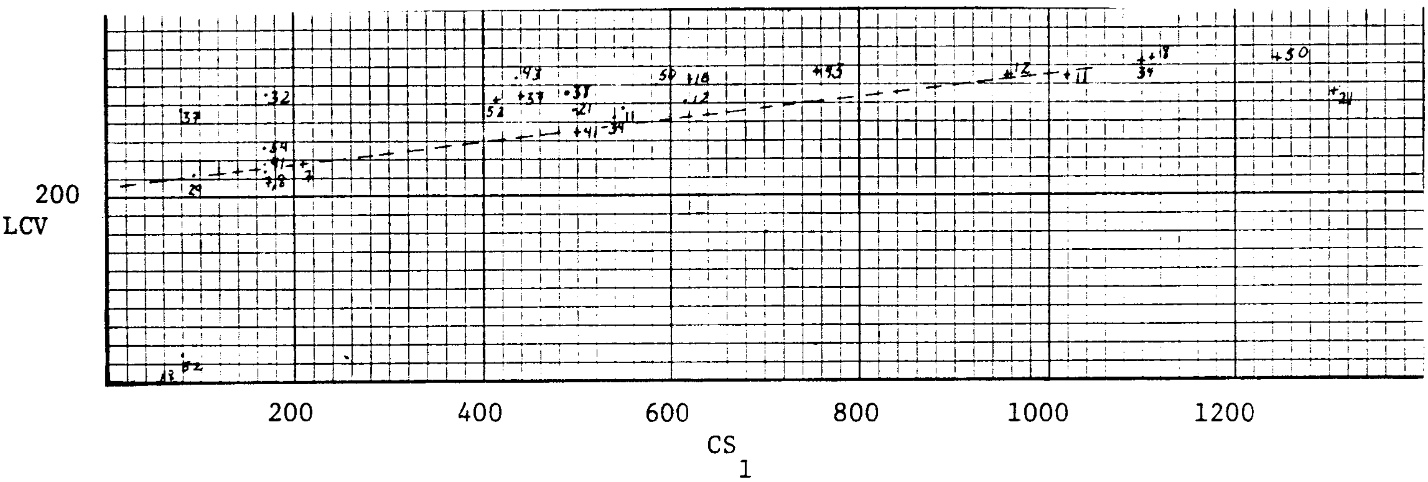
$\Sigma(X-\bar{X})(Y-\bar{Y}) = 406118.8889$

$\hat{X} = 1.2783\ Y + 330.6599$

$\hat{Y} = 0.7815\ X - 258.0820$

$r = 0.9995301$

CS_1, Upper Lake Champlain Valley



	X	Y	$(X-\bar{X})$	$(Y-\bar{Y})$
B29	95	223	-351.5714	-42.0000
B41	172	235	-274.5714	-30.0000
B7,B8	172	227	-274.5714	-38.0000
T7	210	235	-236.5714	-30.0000
T41	502	278	55.4286	13.0000
T12	955	326	508.4286	61.0000
T11	1020	331	537.4286	66.0000

$\underline{n} = 7$

$\bar{X} = 446.5714$

$\bar{Y} = 265.0000$

$\Sigma(X-\bar{X})^2 = 880748.8551$

$\Sigma(Y-\bar{Y})^2 = 13254.0000$

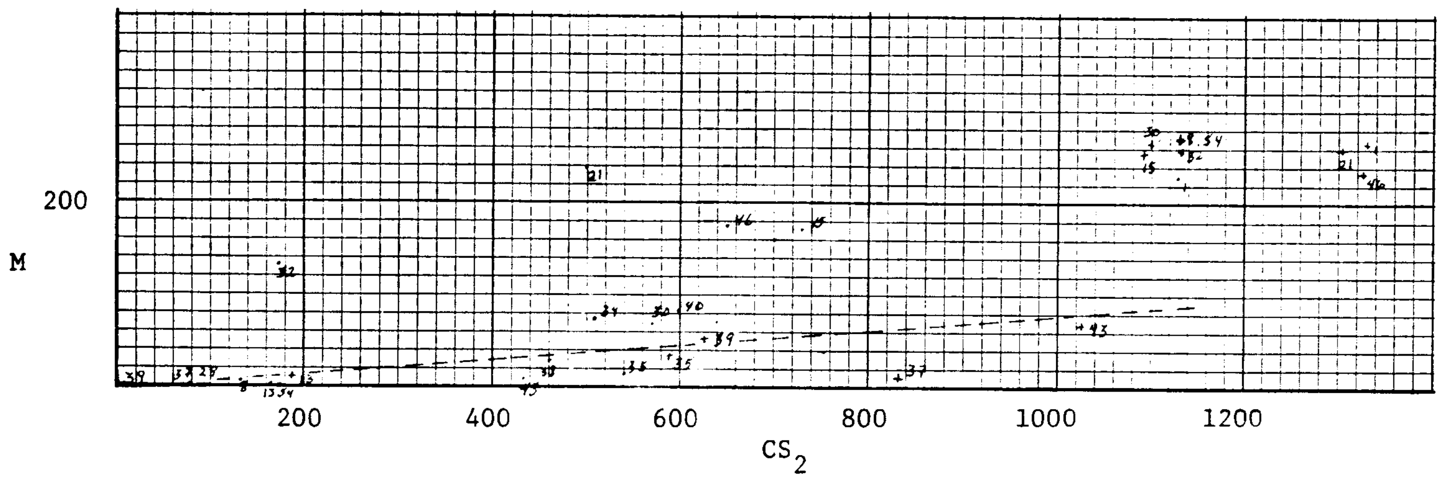
$\Sigma(X-\bar{X})(Y-\bar{Y}) = 107739.0000$

$\hat{X} = 8.1288\ Y - 1707.5583$

$\hat{Y} = 0.1223\ X + 210.3724$

$r = 0.9971797$

CS_2, Minnesota



	X	Y	$(X-\bar{X})$	$(Y-\bar{Y})$
B43	436	7	-194.9814	-65.7142
B38	458.49	26	-172.4914	-46.7143
B30	575	62	-55.9814	-10.7143
B40	600	82	-30.9814	9.2857
T35	592.71	36	-38.2714	-36.7143
T39	624.67	68	-6.3114	-4.7143
B1	1130	228	499.0186	155.2857

$\underline{n} = 7$

$\bar{X} = 630.9814$

$\bar{Y} = 72.7143$

$\Sigma(X-\bar{X})^2 = 322388.8907$

$\Sigma(Y-\bar{Y})^2 = 32185.4154$

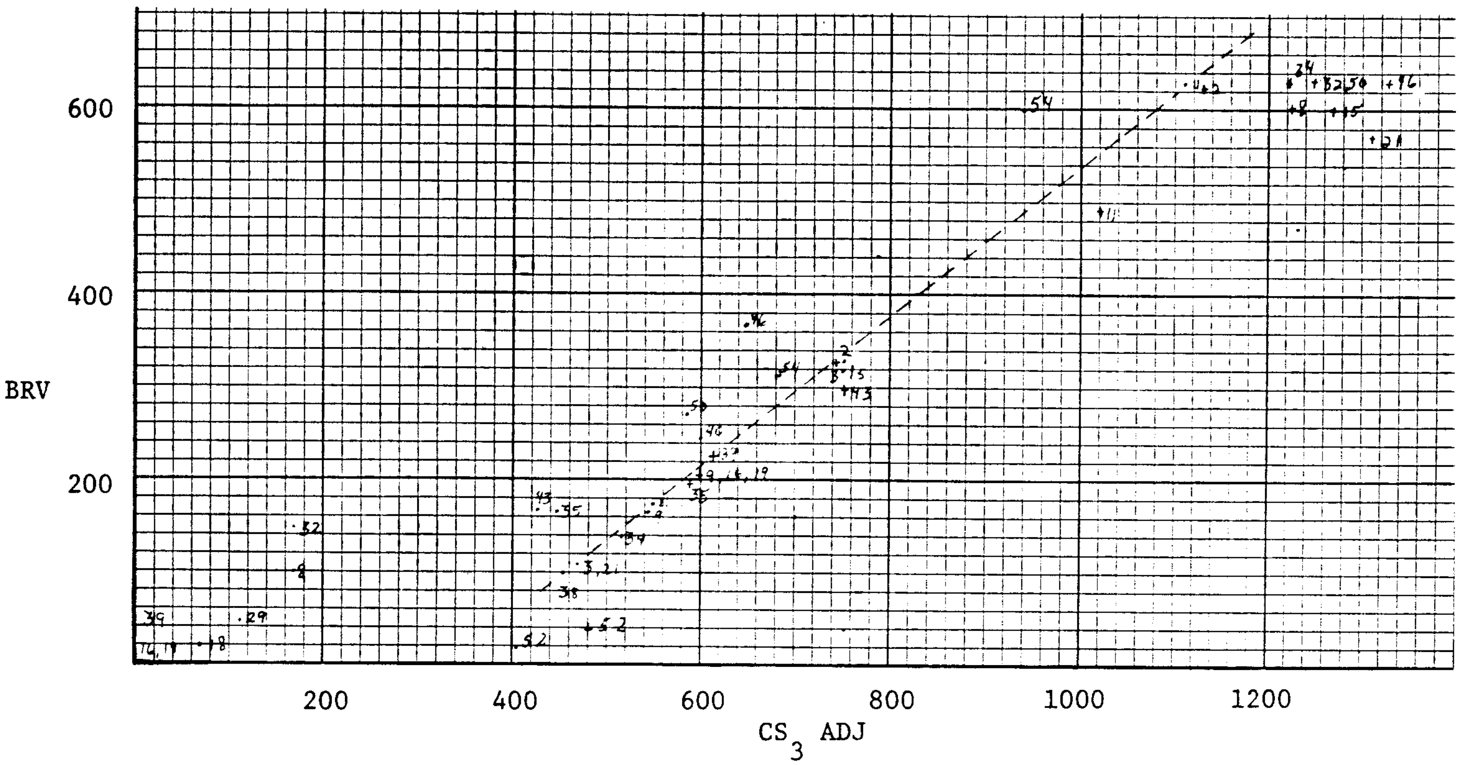
$\Sigma(X-\bar{X})(Y-\bar{Y}) = 100108.3129$

$\hat{X} = 3.1104\ Y + 404.8136$

$\hat{Y} = 0.3105\ X - 123.2183$

$r = 0.9827670$

CS_3 ADJ, Black River Valley



	X	Y	$(X-\bar{X})$	$(Y-\bar{Y})$
B9	545	165	-166.7960	-134.4000
B11	550	167	-161.7960	-132.4000
T9	600	210	-111.7960	-89.4000
B2	750	325	38.2040	25.6000
B1	1113.98	630	402.1840	330.6000

$\underline{n} = 5$

$\bar{X} = 711.7960$

$\bar{Y} = 299.4000$

$\Sigma (X-\bar{X})^2 = 229708.7123$

$\Sigma (Y-\bar{Y})^2 = 153537.2000$

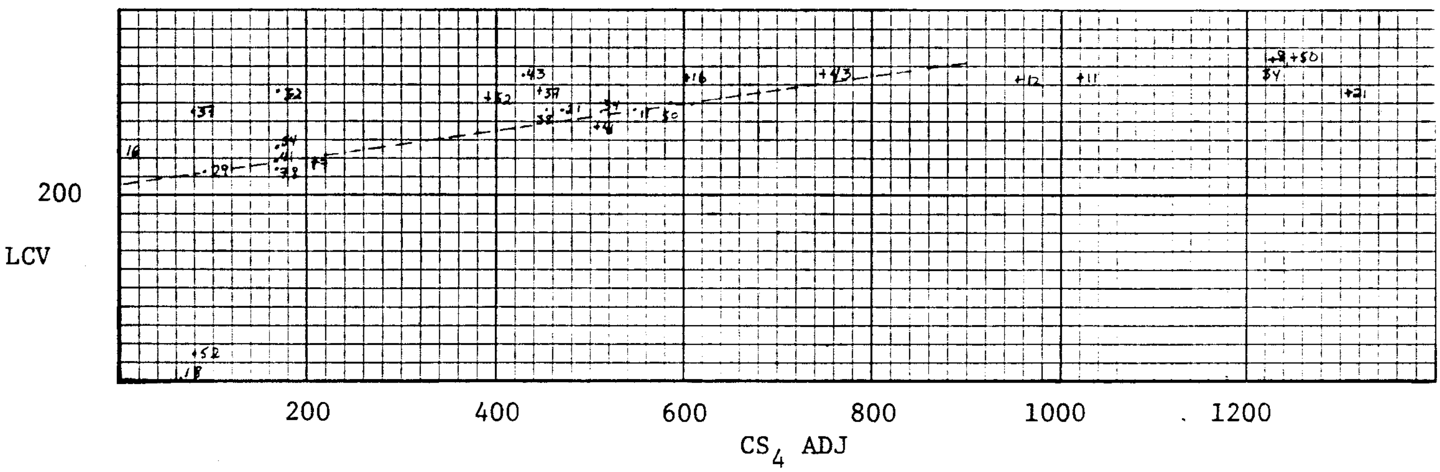
$\Sigma (X-\bar{X})(Y-\bar{Y}) = 187773.7880$

$\hat{X} = 1.2230\ Y + 345.6341$

$\hat{Y} = 0.8174\ X - 282.4527$

$r = 0.9998605$

CS_4 ADJ, Upper Lake Champlain Valley



	X	Y	(X-$\bar{X}$)	(Y-$\bar{Y}$)
B29	95	223	-325.7667	-49.1667
B41	172	235	-248.7667	-37.1667
B34	513.46	283	92.6933	10.8333
B11	544.14	292	123.3733	19.8333
B12	615	300	194.2333	27.8333
B50	585	300	164.2333	27.8333

$n = 6$

$\bar{X} = 420.7667$

$\bar{Y} = 272.1667$

$\Sigma(X-\bar{X})^2 = 256520.9845$

$\Sigma(Y-\bar{Y})^2 = 5858.8333$

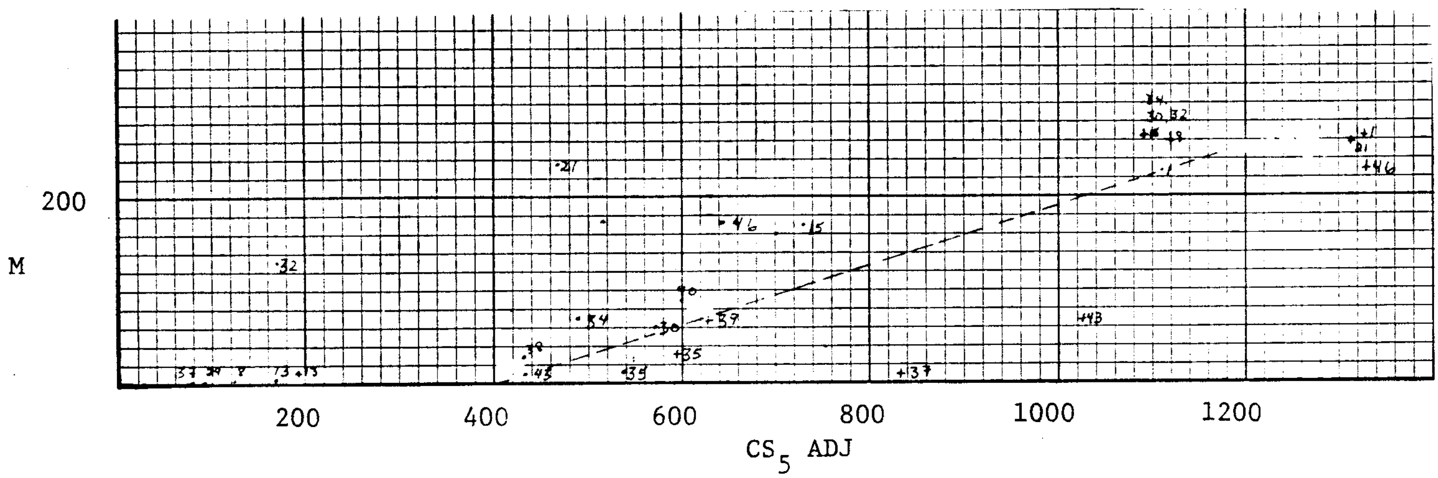
$\Sigma(X-\bar{X})(Y-\bar{Y}) = 38691.0933$

$\hat{X} = 6.6039\ Y - 1376.5924$

$\hat{Y} = 0.1508\ X + 208.7024$

$r = 0.9980308$

CS_5 ADJ, Minnesota



	X	Y	$(X-\bar{X})$	$(Y-\bar{Y})$
B43	436	7	-252.5100	-84.2500
B30	575	62	-113.5100	-29.2500
T39	626.92	68	-61.5900	-23.2500
B1	1116.12	228	427.6100	136.7500

$\underline{n} = 4$

$\bar{X} = 688.5100$

$\bar{Y} = 91.2500$

$\Sigma(X-\bar{X})^2 = 263289.4606$

$\Sigma(Y-\bar{Y})^2 = 27194.7500$

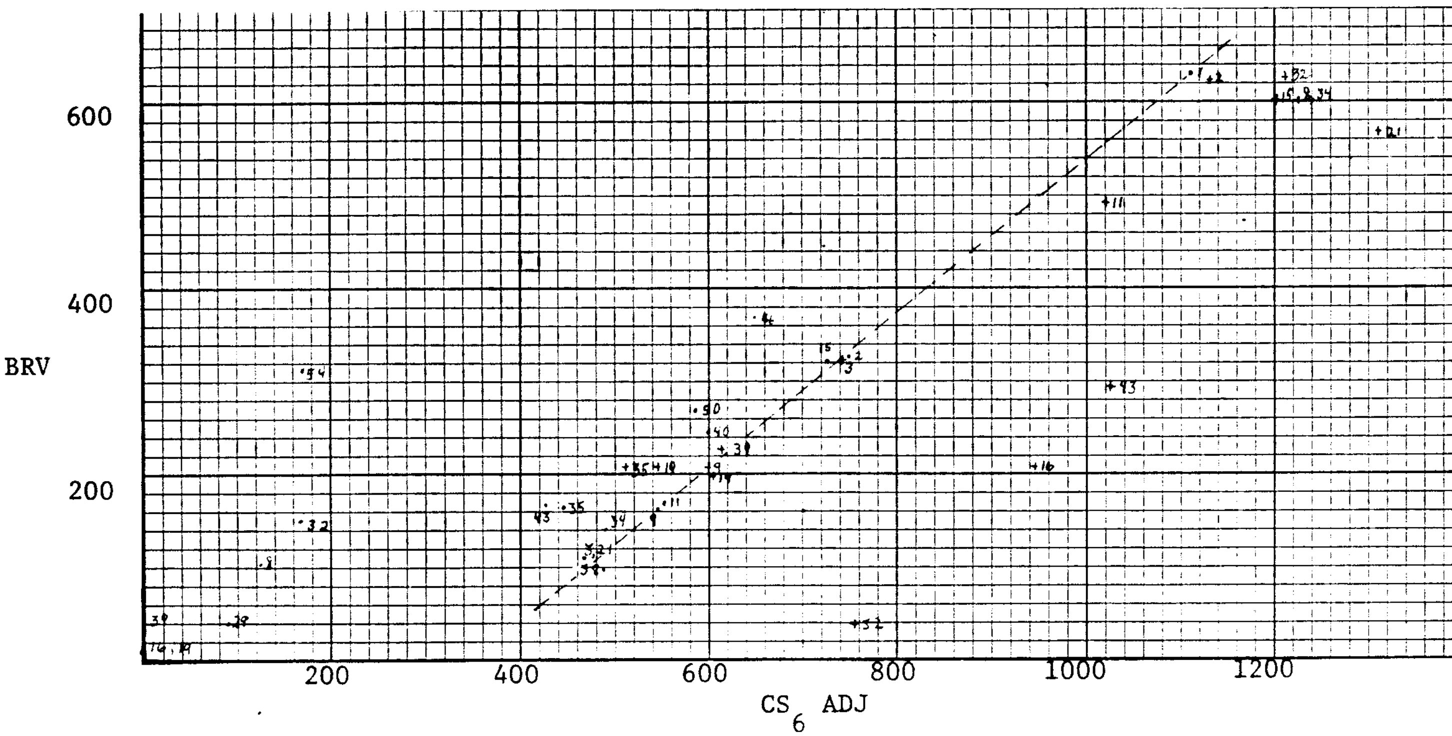
$\Sigma(X-\bar{X})(Y-\bar{Y}) = 84501.7700$

$\hat{X} = 3.1073\ Y + 404.9705$

$\hat{Y} = 0.3209\ X - 129.7247$

$r = 0.9986345$

CS_6 ADJ, Black River Valley



	X	Y	$(X-\overline{X})$	$(Y-\overline{Y})$
B1	1113.43	630	402.7440	330.6000
T3	745	325	34.3140	25.6000
T9	600	210	-110.6860	-89.4000
B9	545	165	-165.6860	-134.4000
B11	550	167	-160.6860	-132.4000

$\underline{n} = 5$

$\overline{X} = 710.6860$

$\overline{Y} = 299.4000$

$\Sigma(X-\overline{X})^2 = 228903.4119$

$\Sigma(Y-\overline{Y})^2 = 153537.2000$

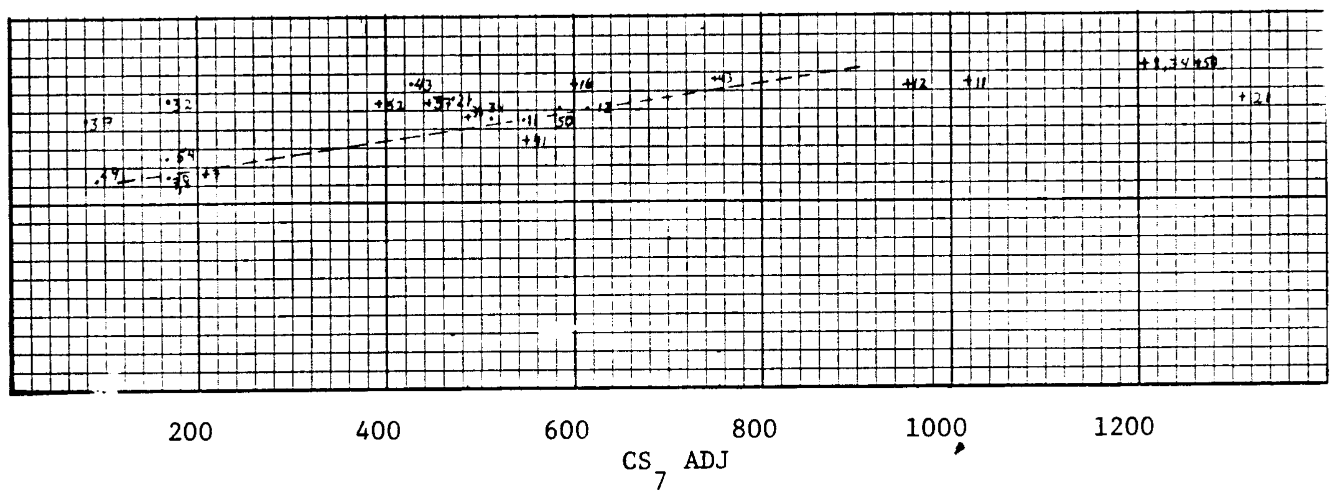
$\Sigma(X-\overline{X})(Y-\overline{Y}) = 187463.9580$

$\hat{X} = 1.2210\ Y + 345.1283$

$\hat{Y} = 0.8190\ X - 282.6272$

$r = 0.9999651$

CS_7 ADJ, Upper Lake Champlain Valley



	X	Y	$(X-\bar{X})$	$(Y-\bar{Y})$
B7	172	227	-213.2850	-36.5000
T7	210	235	-175.2850	-28.5000
B11	544.14	292	158.8550	28.5000
B12	615	300	229.7150	36.5000

$n = 4$

$\bar{X} = 385.2850$

$\bar{Y} = 263.5000$

$\Sigma(X-\bar{X})^2 = 154219.2147$

$\Sigma(Y-\bar{Y})^2 = 4289.0000$

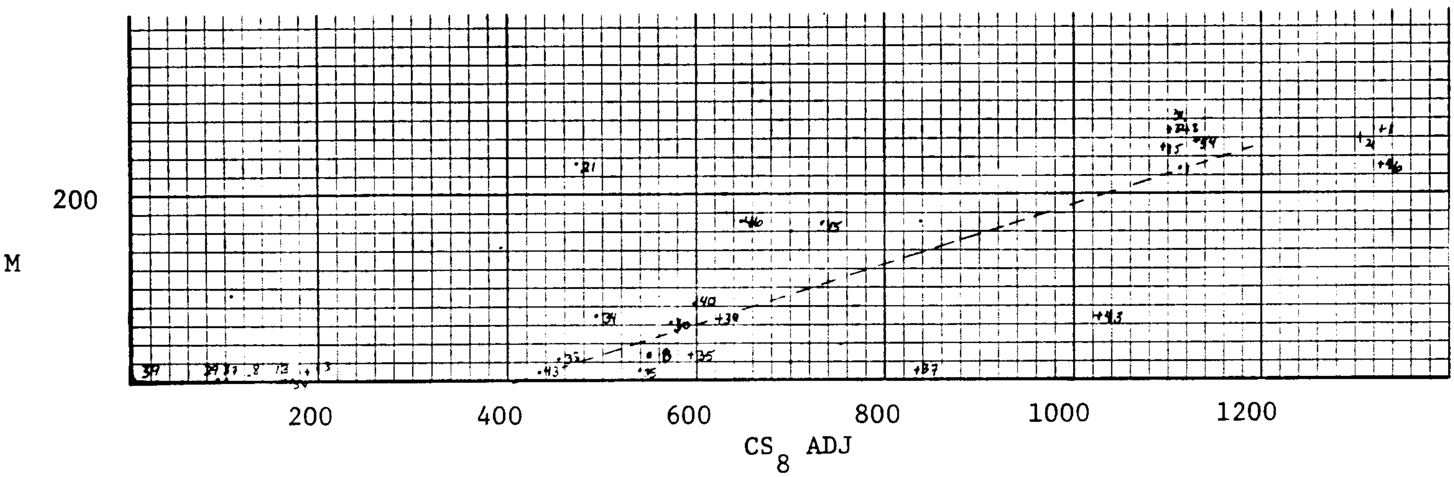
$\Sigma(X-\bar{X})(Y-\bar{Y}) = 25692.4900$

$\hat{X} = 5.9903\ Y - 1193.1648$

$\hat{Y} = 0.1666\ X + 199.3126$

$r = 0.9989849$

CS_8 ADJ, Minnesota



	X	Y	$(X-\bar{X})$	$(Y-\bar{Y})$
B43	436	7	-289.7600	-94.0000
T39	626.92	68	-98.8400	-33.0000
B1	1114.36	228	388.6000	127.0000

$\underline{n} = 3$

$\bar{X} = 725.9600$

$\bar{Y} = 101.0000$

$\Sigma(X-\bar{X})^2 = 244740.1632$

$\Sigma(Y-\bar{Y})^2 = 26054.0000$

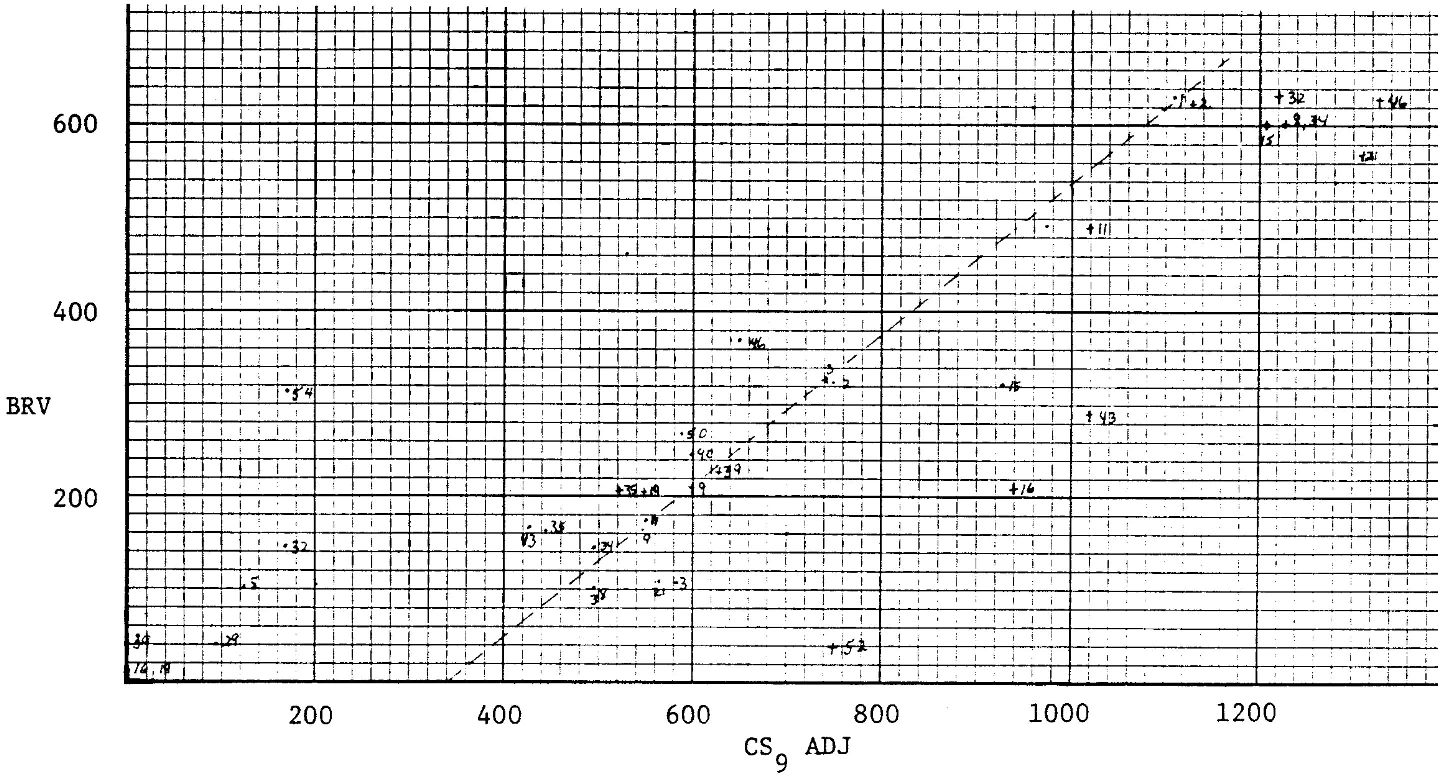
$\Sigma(X-\bar{X})(Y-\bar{Y}) = 79851.3600$

$\hat{X} = 3.0648\ Y + 416.2111$

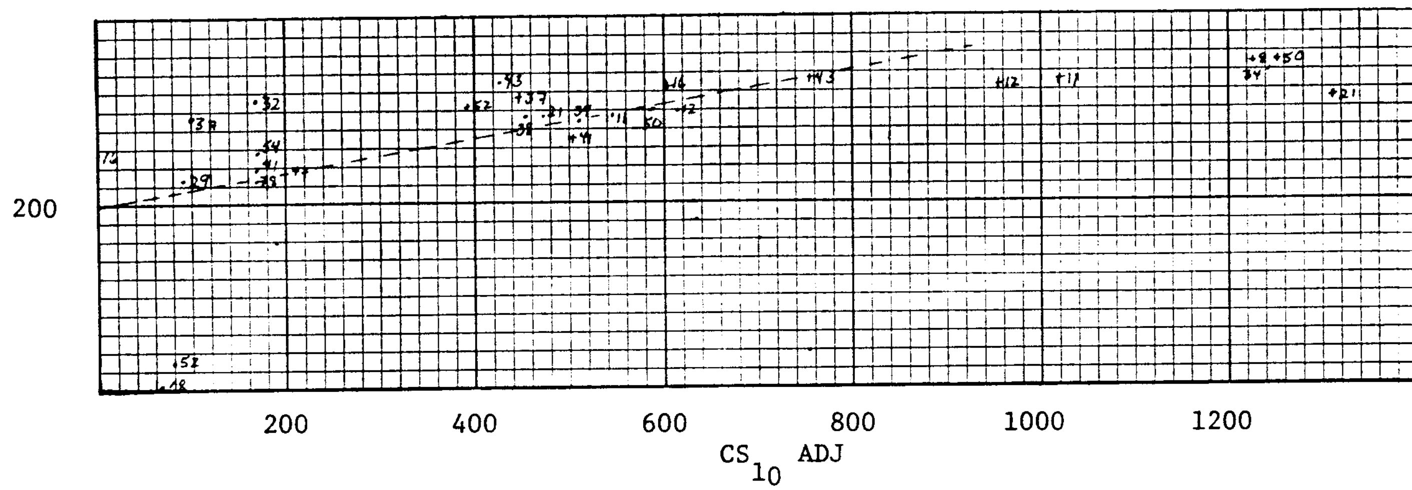
$\hat{Y} = 0.3263\ X - 135.\ 7936$

$r = 0.9999826$

CS_9 ADJ, Black River Valley



CS_{10} ADJ, Upper Lake Champlain Valley



(CS_{11} ADJ not plotted, since it is the same as CS_8 ADJ.)

	Base section	$\widehat{BS}$ of BRV	CS_1	$\widehat{CS}_1$ of LCV	CS_2
1	1130-1330	1135.99	1130-1330	-	1130-1330
2	750-1125	746.11-1129.60	746.11-1129.60	-	746.11-1129.60
3	585-745	471.27-746.11	471.27-746.11	-	471.27-746.11
4	545-629	-	545-629	-	545-629
5	670-1570	-	670-1570	-	670-1570
6	95-221	-	95-221	-	95-221
7	172-210	-	172-210	137.68-202.71	137.68-210
8	172-1110	461.05-1097.64	172-1110	137.68-1121.26	137.68-1121.26
9	545-600	541.58-599.10	541.58-600	-	541.58-600
10	1345-1560	-	1345-1560	-	1345-1560
11	550-1020	544.14-963.42	544.14-1020	666.05-983.07	544.14-1020
12	615-955	-	615-955	731.08-942.43	615-955
13	166-188	-	166-188	-	166-188
14	150-524	-	150-524	-	150-524
15	-	739.72-1097.64	739.72-1097.64	-	739.72-1097.64
16	0-545	343.44-599.10	0-599.10	381.54-942.43	0-942.43
17	1365-1585	-	1365-1585	-	1365-1585
18	65-1585	356.26-982.59	65-1585	-1707.56-1153.78	-1707.56-1585
19	0-545	343.44-599.10	0-599.10	-	0-599.10
20	0-1100	-	0-1100	-	0-1100
21	590-1305	471.27-1059.29	471.27-1305	682.31-836.76	471.27-1305
22	-	-	-	-	-
23	955-1200	-	955-1200	-	955-1200
24	1095-1545	-	1095-1545	-	1095-1545
25	685-950	-	685-950	-	685-950
26	1350-1570	-	1350-1570	-	1350-1570
27	1380-1500	-	1380-1500	-	1380-1500
28	-	-	-	-	-

	Base section	$\hat{BS}$ of BRV	CS_1	$\hat{CS}_1$ of LCV	CS_2
29	95-1545	381.79-1123.21	95-1545	105.16-1048.10	95-1545
30	575-1105	-	575-1105	-	575-1105
31	1370-1535	-	1370-1535	-	1370-1535
32	172-1040	513.46-1135.99	172-1135.99	836.76	172-1135.99
33	-	-	-	-1601.88--350.05	-1601.88--350.05
34	610-995	513.46-1104.03	513.46-1104.03	592.89-1088.75	513.46-1104.03
35	-	541.58-592.71	541.58-592.71	-	541.58-592.71
36	-	-	-	15.75-202.71	15.75-202.71
37	80-441	-	80-441	682.31-836.76	80-836.76
38	545-1595	458.49-1127.04	458.49-1595	666.05-1153.78	458.49-1595
39	0-610	381.79-624.67	0-624.67	-	0-624.67
40	600-1565	640.01-1135.99	600-1565	-	600-1565
41	172-502	-	172-502	202.71-552.25	172-552.25
42	1175-1560	-	1175-1560	-	1175-1560
43	436-755	541.58-711.59	436-755	983.07-1023.72	436-1023.72
44	-	-	-	470.96	470.96
45	-	-	-	-	-
46	650-1325	802.35-1135.99	650-1325	-	650-1325
47	-	-	-	-813.39-528.88	-813.39-528.88
48	1145-1350	-	1145-1350	-	1145-1350
49	760-1570	-	760-1570	-	760-1570
50	585-1245	675.80-1123.21	585-1245	731.08-1129.39	585-1245
51	680-745	-	680-745	-	680-745
52	80-235	356.22-381.79	80-381.79	-1463.69-755.49	-1463.69-755.47
53	-	-	-	-	-
54	172-1130	735.88-1096.36	172-1130	357.16	172-1130
55	685-940	-	685-940	-	685-940
56	-	-	-	-	-

	$\widehat{CS}_2$ of M	CS_3	CS_3 ADJ	$\widehat{CS}_3$ of BRV	CS_4
1	1113.98-1225.96	1113.98-1330	1113.98-1330	1116.12	1113.98-1330
2	-	746.11-1129.60	750-1125	743.11-1110.01	743.11-1129.60
3	-	471.27-746.11	585-745	480.16-743.11	471.27-746.11
4	-	545-629	545-629	-	545-629
5	-	670-1570	670-1570	-	670-1570
6	-	95-221	95-221	-	95-221
7	-	137.68-210	137.68-210	-	137.68-210
8	417.26-1225.96	137.68-1225.96	137.68-1225.96	407.38-1079.43	137.68-1225.96
9	-	541.58-600	545-600	547.43-602.46	541.58-602.46
10	-	1345-1560	1345-1560	-	1345-1560
11	-	544.14-1020	550-1020	549.88-951.02	544.14-1020
12	-	615-955	615-955	-	615-955
13	407.92-431.25	166-431.25	166-431.25	-	166-431.25
14	-	150-524	150-524	-	150-524
15	930.47-1204.19	739.72-1204.19	930.47-1204.19	736.99-1079.43	736.99-1204.19
16	-	0-942.43	0-942.43	357.86-602.46	0-942.43
17	-	1365-1585	1365-1585	-	1365-1585
18	404.81-1225.96	-1707.56-1585	-1707.56-1585	370.09-969.36	-1707.56-1585
19	-	0-599.10	0-545	357.86-602.46	0-602.46
20	-	0-1100	0-1100	-	0-1100
21	1148.20-1213.52	471.27-1305	590-1305	480.16-1042.74	471.27-1305
22	439.03-616.32	439.03-616.32	439.03-616.32	-	439.03-616.32
23	-	955-1200	955-1200	-	955-1200
24	-	1095-1545	1095-1545	-	1095-1545
25	-	685-950	685-950	-	685-950
26	-	1350-1570	1350-1570	-	1350-1570
27	-	1380-1500	1380-1500	-	1380-1500
28	591.44-1225.96	591.44-1225.96	591.44-1225.96	-	591.44-1225.96

	$\widehat{CS}_2$ of M	CS_3	CS_3 ADJ	$\widehat{CS}_3$ of BRV	CS_4
29	404.81-1225.96	95-1545	95-1545	394.55-1103.89	95-1545
30	597.66-1225.96	575-1225.96	575-1225.96	-	575-1225.96
31	-	1370-1535	1370-1535	-	1370-1535
32	821.61-1216.63	172-1216.63	172-1216.63	520.52-1116.12	172-1216.63
33	-	-1601.88--350.05	-1601.88--350.05	-	-1601.88--350.05
34	634.98-1225.96	513.46-1225.96	592.89-1225.96	520.52-1085.55	513.46-1225.96
35	445.25-516.79	445.25-592.71	445.25-516.79	547.43-596.35	445.25-596.35
36	-	15.75-202.71	15.75-202.71	-	15.75-202.71
37	407.92-431.25	80-836.76	80-836.76	-	80-836.76
38	485.68-1141.98	458.49-1595	485.68-1595	467.93-1107.56	458.49-1595
39	404.81-616.32	0-624.67	0-616.32	394.55-626.92	0-626.92
40	659.87-1225.96	600-1565	600-1565	641.60-1116.12	600-1565
41	-	172-552.25	172-552.25	-	172-552.25
42	-	1175-1560	1175-1560	-	1175-1560
43	426.59-616.32	426.59-1023.72	426.59-1023.72	547.43-710.09	426.59-1023.72
44	-	470.96	470.96	-	470.96
45	457.69-547.89	457.69-547.89	457.69-547.89	-	457.69-547.89
46	952.24-1129.54	650-1325	650-1325	796.92-1116.12	650-1325
47	-	-813.39--528.88	-813.39--528.88	-	-813.39--528.88
48	-	1145-1350	1145-1350	-	1145-1350
49	-	760-1570	760-1570	-	760-1570
50	-	585-1245	585-1245	675.84-1103.89	585-1245
51	-	680-745	680-745	-	680-745
52	-	-1463.69-755.47	-1463.69-755.47	370.09-394.55	-1463.69-755.47
53	404.81-482.57	404.81-482.57	404.81-482.57	-	404.81-482.57
54	404.81-1213.52	172-1213.52	172-1213.52	733.33-1078.21	172-1213.52
55	-	685-940	685-940	-	685-940
56	439.03-467.02	439.03-467.02	439.03-467.02	-	439.03-467.02

	CS_4 ADJ	$\hat{CS}_4$ of LCV	CS_5	CS_5 ADJ	$\hat{CS}_5$ of M
1	1113.98-1330	-	1113.98-1330	1116.12-1330	1113.43-1225.30
2	743.11-1129.60	-	743.11-1129.60	743.11-1129.69	-
3	471.27-746.11	-	471.27-746.11	471.27-746.11	-
4	545-629	-	545-629	545-629	-
5	670-1570	-	670-1579	670-1570	-
6	95-221	-	95-221	95-221	-
7	172-210	122.49-175.32	122.49-210	122.49-210	-
8	172-1225.96	122.49-921.56	122.49-1225.96	122.49-1121.26	417.40-1225.30
9	541.58-602.46	-	541.58-602.46	541.58-602.46	-
10	1345-1560	-	1345-1560	1345-1560	-
11	544.14-1020	551.75-809.30	544.14-1020	544.14-1020	-
12	615-955	604.58-776.28	604.58-955	604.58-955	-
13	166-431.25	-	166-431.25	166-188	408.08-431.38
14	150-524	-	150-524	150-524	-
15	736.99-1204.19	-	736.99-1204.19	736.99-1097.64	930.10-1203.55
16	0-602.46	320.61-776.28	0-942.43	0-942.43	-
17	1365-1585	-	1365-1585	1365-1585	-
18	65-1585	-1376.59-947.98	-1707.56-1585	-1707.56-1585	404.97-1225.30
19	0-602.46	-	0-602.46	0-602.46	-
20	0-1100	-	0-1100	0-1100	-
21	471.27-1305	564.95-690.43	471.27-1305	471.27-1305	1147.62-1212.87
22	439.03-616.32	-	439.03-616.32	-	439.15-616.27
23	955-1200	-	955-1200	955-1200	-
24	1095-1545	-	1095-1545	1095-1545	-
25	685-950	-	685-950	685-950	-
26	1350-1570	-	1350-1570	1350-1570	-
27	1380-1500	-	1380-1500	1380-1500	-
28	591.44-1225.96	-	591.44-1225.96	-	591.41-1225.30

	CS_4 ADJ	$\widehat{CS_4}$ of LCV	CS_5	CS_5 ADJ	$\widehat{CS_5}$ of M
29	95-1545	96.08-862.13	95-1545	95-1545	404.97-1225.30
30	575-1225.96	-	575-1225.96	575-1105	597.62-1225.30
31	1370-1535	-	1370-1535	1370-1535	-
32	172-1216.63	690.43	172-1216.63	172-1135.99	821.35-1215.98
33	-	-1290.74--273.74	-1601.88--273.74	-1601.88--273.74	-
34	513.46-1225.96	492.31-895.15	492.31-1225.96	492.31-1104.03	634.91-1225.30
35	445.25-596.35	-	445.25-596.35	541.58-596.35	445.37-516.83
36	-	23.43-175.32	15.75-202.71	15.75-202.71	-
37	80-441	564.95-690.43	80-836.76	80-836.76	404.08-431.38
38	458.49-1595	551.75-947.98	458.49-1595	458.49-1595	485.76-1141.40
39	0-626.92	-	0-626.92	0-626.92	404.97-616.27
40	600-1565	-	600-1565	600-1565	659.77-1225.30
41	172-502	175.32-459.29	172-552.25	172-552.25	-
42	1175-1560	-	1175-1560	1175-1560	-
43	426.59-755	809.30-842.32	426.59-1023.72	436-1023.72	426.72-616.27
44	-	393.25	393.25	393.25	-
45	457.69-547.89	-	457.69-547.89	-	457.79-547.91
46	650-1325	-	650-1325	650-1325	951.86-1128.97
47	-813.39--528.88	-	-650.16--419.03	-813.39--419.03	-
48	1145-1350	-	1145-1350	1145-1350	-
49	760-1570	-	760-1570	760-1570	-
50	585-1245	604.58-928.17	585-1245	585-1245	-
51	680-745	-	680-745	680-745	-
52	80-394.55	-1178.48-624.39	-1463.69-755.47	-1463.69-755.47	-
53	404.81-482.57	-	404.81-482.57	-	404.97-482.65
54	172-1213.52	300.80	172-1213.52	172-1130	404.97-1212.87
55	685-940	-	685-940	685-940	-
56	439.03-467.02	-	439.03-467.02	-	439.15-467.12

	CS_6	CS_6 ADJ	$\hat{CS}_6$ of BRV	CS_7	CS_7 ADJ
1	1113.43-1330	1113.43-1330	1114.36	1113.43-1330	1113.43-1330
2	743.11-1129.60	750-1125	741.95-1108.25	741.95-1129.60	741.95-1129.60
3	471.27-746.11	585-745	479.44-741.95	471.27-746.11	471.27-746.11
4	545-629	545-629	-	545-629	545-629
5	670-1570	670-1570	-	670-1570	670-1570
6	95-221	95-221	-	95-221	95-221
7	122.49-210	122.49-210	-	122.49-210	172-210
8	122.49-1225.96	122.49-1225.96	469.67-1077.73	122.49-1225.96	172-1225.96
9	541.58-602.46	545-600	546.59-601.54	541.58-602.46	541.58-602.46
10	1345-1560	1345-1560	-	1345-1560	1345-1560
11	544.14-1020	550-1020	549.04-949.52	544.14-1020	544.14-1020
12	604.58-955	604.58-955	-	604.58-955	615-955
13	166-431.38	166-431.38	-	166-431.58	166-431.58
14	150-524	150-524	-	150-524	150-524
15	736.99-1204.19	930.10-1204.19	735.85-1077.73	735.85-1204.19	735.85-1204.19
16	0-942.43	0-942.43	357,34-601.54	0-942.43	0-602.46
17	1365-1585	1365-1585	-	1365-1585	1365-1585
18	-1707.56-1585	-1707.56-1585	369.55-967.84	-1707.56-1585	65-1585
19	0-602.46	0-545	357.34-601.54	0-602.46	0-602.46
20	0-1100	0-1100	-	0-1100	0-1100
21	471.27-1305	564.95-1305	479.44-1041.10	471.27-1305	471.27-1305
22	439.03-616.32	439.03-616.32	-	439.03-616.32	439.03-616.32
23	955-1200	955-1200	-	955-1200	955-1200
24	1095-1545	1095-1545	-	1095-1545	1095-1545
25	685-950	685-950	-	685-950	685-950
26	1350-1570	1350-1570	-	1350-1570	1350-1570
27	1380-1500	1380-1500	-	1380-1500	1380-1500
28	591.41-1225.96	591.41-1225.96	-	591.41-1225.96	591.41-1225.96

	CS_6	CS_6 ADJ	$\hat{CS}_6$ of BRV	CS_7	CS_7 ADJ
29	95-1545	95-1545	393.97-1102.15	95-1545	95-1545
30	575-1225.96	575-1225.96	-	575-1225.96	575-1225.96
31	1370-1535	1370-1535	-	1370-1535	1370-1535
32	172-1216.63	172-1216.63	519.73-1114.36	172-1216.63	172-1216.63
33	-1601.88--273.74	-1601.88--273.74	-	-1601.88--273.74	-
34	492.31-1225.96	492.31-1225.96	519.73-1083.83	492.31-1225.96	513.46-1225.96
35	445.25-596.35	445.25-516.83	546.59-595.43	445.25-596.35	445.25-596.35
36	15.75-202.71	15.75-202.71	-	15.75-202.71	-
37	80-836.76	80-836.76	-	80-836.76	80-441
38	458.49-1595	485.68-1595	467.23-1105.81	458.49-1595	458.49-1595
39	0-626.92	0-616.32	393.97-625.96	0-626.92	0-626.92
40	600-1565	600-1565	640.61-1114.36	600-1565	600-1565
41	172-552.25	172-552.25	-	172-552.25	172-552.25
42	1175-1560	1175-1560	-	1175-1560	1175-1560
43	426.59-1023.72	426.59-1023.72	546.59-708.99	426.59-1023.72	426.59-755
44	393.25	393.25	-	393.25	-
45	457.69-547.91	457.69-547.91	-	457.69-547.91	457.69-547.91
46	650-1325	650-1325	795.68-1114.36	650-1325	650-1325
47	-813.39--419.03	-813.39--419.03	-	-813.39--419.03	-
48	1145-1350	1145-1350	-	1145-1350	1145-1450
49	760-1570	760-1570	-	760-1570	760-1570
50	585-1245	585-1245	674.80-1102.15	585-1245	585-1245
51	680-745	680-745	-	680-745	680-745
52	-1463.69-755.47	-1463.69-755.47	369.55-393.97	-1463.69-755.47	80-394.55
53	404.81-482.65	404.81-482.65	-	404.81-482.65	404.81-482.65
54	172-1213.52	172-1213.52	732.19-1076.51	172-1213.52	172-1213.52
55	685-940	685-940	-	685-940	685-940
56	439.03-467.12	439.03-467.12	-	439.03-467.12	439.03-467.12

	$\hat{CS}_7$ of LCV	CS_8	CS_8 ADJ	$\hat{CS}_8$ of M	$\hat{CS}_9$
1	-	1113.43-1330	1114.36-1330	1114.99-1225.32	1113.43-1330
2	-	741.95-1129.60	741.95-1129.60	-	741.95-1129.60
3	-	471.27-746.11	471.27-746.11	-	471.27-746.11
4	-	545-629	545-629	-	545-629
5	-	670-1570	670-1570	-	670-1570
6	-	95-221	95-221	-	95-221
7	166.63-214.56	122.49-214.56	122.49-214.56	-	122.49-214.56
8	166.63-891.46	122.49-1225.96	122.49-1121.26	428.47-1225.32	122.49-1225.96
9	-	541.58-602.46	541.58-602.46	-	541.58-602.46
10	-	1345-1560	1345-1560	-	1345-1560
11	556.00-789.62	544.14-1020	544.14-1020	-	544.14-1020
12	603.93-759.67	603.93-955	603.93-955	-	603.93-955
13	-	166-431.38	166-188	419.28-442.26	166-442.26
14	-	150-524	150-524	-	150-524
15	-	735.85-1204.19	735.85-1097.64	934.16-1203.86	735.85-1204.19
16	346.34-759.67	0-942.43	0-942.43	-	0-942.43
17	-	1365-1585	1365-1585	-	1365-1585
18	-1193.16-915.42	-1707.56-1585	-1707.56-1585	416.21-1225.32	-1707.56-1585
19	-	0-602.46	0-602.46	-	0-602.46
20	-	0-1100	0-1100	-	0-1100
21	567.98-681.80	471.27-1305	471.27-1305	1148.70-1213.06	471.27-1305
22	-	439.03-616.32	-	449.92-624.62	439.03-624.62
23	-	955-1200	955-1200	-	955-1200
24	-	1095-1545	1095-1545	-	1095-1545
25	-	685-950	685-950	-	685-950
26	-	1350-1570	1350-1570	-	1350-1570
27	-	1380-1500	1380-1500	-	1380-1500
28	-	591.41-1225.96	-	600.10-1225.32	591.41-1225.96

	$\hat{CS}_7$ of LCV	CS_8	CS_8 ADJ	$\hat{CS}_8$ of M	CS_9
29	142.67-837.55	95-1545	95-1545	416.21-1225.32	95-1545
30	-	575-1225.96	575-1105	606.23-1225.32	575-1225.96
31	-	1370-1535	1370-1535	-	1370-1535
32	681.80	172-1216.63	172-1135.99	826.89-1216.12	172-1216.63
33	-1115.29--192.78	-1601.88--192.78	-1601.88--192.78	-	-1601.88--192.78
34	502.09-867.50	492.31-1225.96	492.31-1104.03	643.01-1225.32	492.31-1225.96
35	-	445.25-596.35	541.58-596.35	456.05-526.54	445.25-596.35
36	76.78-214.56	15.75-214.56	15.75-214.56	-	15.75-214.56
37	567.98-681.80	80-836.76	80-836.76	419.28-442.26	80-836.76
38	556.00-915.42	458.49-1595	458.49-1595	495.90-1142.57	458.49-1595
39	-	0-626.92	0-626.92	416.21-624.62	0-626.92
40	-	600-1565	600-1565	667.52-1225.32	600-1565
41	214.56-472.14	172-552.25	172-552.25	-	172-552.25
42	-	1175-1560	1175-1560	-	1175-1560
43	789.62-819.58	426.59-1023.72	436-1023.72	437.66-624.62	426.59-1023.72
44	412.24	393.25	393.25	-	393.25
45	-	457.69-547.91	-	468.31-557.19	457.69-557.19
46	-	650-1325	650-1325	955.62-1130.31	650-1325
47	-534.23--324.57	-813.39--324.57	-813.39--324.57	-	-813.39--324.57
48	-	1145-1350	1145-1350	-	1145-1350
49	-	760-1570	760-1570	-	760-1570
50	603.93-897.45	585-1245	585-1245	-	585-1245
51	-	680-745	680-745	-	680-745
52	-1013.36-621.90	-1463.69-755.47	-1463.69-755.47	-	-1463.69-755.47
53	-	404.81-482.63	-	416.21-492.83	404.81-492.83
54	328.37	172-1213.52	172-1130	416.21-1213.06	172-1213.52
55	-	685-940	685-940	-	685-940
56	-	439.03-467.12	-	449.92-477.51	439.03-477.51

	CS_9 ADJ	CS_{10} ADJ	CS_{11} ADJ
1	1113.43-1330	1113.43-1330	1114.36-1330
2	750-1125	741.95-1129.60	741.95-1129.60
3	585-745	471.27-746.11	471.27-746.11
4	545-629	545-629	545-629
5	670-1570	670-1570	670-1570
6	95-221	95-221	95-221
7	122.49-214.56	172-210	122.49-214.56
8	122.49-1225.96	172-1225.96	122.49-1121.26
9	545-600	541.58-602.46	541.58-602.46
10	1345-1560	1345-1560	1345-1560
11	550-1020	544.14-1020	544.14-1020
12	603.93-955	615-955	603.93-955
13	166-442.26	166-442.26	166-188
14	150-524	150-524	150-524
15	930.10-1204.19	735.85-1204.19	735.85-1097.64
16	0-942.43	0-602.46	0-942.43
17	1365-1585	1365-1585	1365-1585
18	-1707.56-1585	65-1585	-1707.56-1585
19	0-545	0-602.46	0-602.46
20	0-1100	0-1100	0-1100
21	564.95-1305	471.27-1305	471.27-1305
22	439.03-624.62	439.03-624.62	-
23	955-1200	955-1200	955-1200
24	1095-1545	1095-1545	1095-1545
25	685-950	685-950	685-950
26	1350-1570	1350-1570	1350-1570
27	1380-1500	1380-1500	1380-1500
28	591.41-1225.96	591.41-1225.96	-

NOTE: CS_9 is the final Composite Standard Reference section. In the third round of recorrelation CS_9 was adjusted to remove values from Black River valley (CS_9 ADJ), Lake Champlain valley (CS_{10} ADJ), and Minnesota (CS_{11} ADJ). Regression equations were not calculated because range-zones that would have been used to compute them were the same as values used in the second round of recorrelation.

	CS_9 ADJ	CS_{10} ADJ	CS_{11} ADJ
29	95-1545	95-1545	95-1545
30	575-1225.96	575-1225.96	575-1105
31	1370-1535	1370-1535	1370-1535
32	172-1216.63	172-1216.63	172-1135.99
33	-1601.88--192.78	-	-1601.88--192.78
34	492.31-1225.96	513.46-1225.96	492.31-1104.03
35	445.25-526.54	445.25-596.35	541.58-596.35
36	15.75-214.56	-	15.75-214.56
37	80-836.76	80-442.06	80-836.76
38	485.68-1595	458.49-1595	458.49-1595
39	0-624.62	0-626.92	0-626.92
40	600-1565	600-1565	600-1565
41	172-552.25	172-502	172-552.25
42	1175-1560	1175-1560	1175-1560
43	426.59-1023.72	426.59-755	436-1023.72
44	393.25	-	393.25
45	457.69-557.19	457.69-557.10	-
46	650-1325	650-1325	650-1325
47	-813.39--324.57	-	-813.39--324.57
48	1145-1350	1145-1350	1145-1350
49	760-1570	760-1570	760-1570
50	585-1245	585-1245	585-1245
51	680-745	680-745	680-745
52	-1463.69-755.47	80-394.55	-1463.69-755.47
53	404.81-492.83	404.81-492.83	-
54	172-1213.52	172-1213.52	172-1130
55	685-940	685-940	685-940
56	439.03-477.51	439.03-477.51	-

NOTE: CS_9 is the final Composite Standard Reference section. In the third round of recorrelation CS_9 was adjusted to remove values from Black River valley (CS_9 ADJ), Lake Champlain valley (CS_{10} ADJ), and Minnesota (CS_{11} ADJ). Regression equations were not calculated because range-zones that would have been used to compute them were the same as values used in the second round of recorrelation.